South African Journal of Botany 2001, 67: 433–438
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SOUTH AFRICAN JOURNAL
OF BOTANY
ISSN 0254–6299

The progression of a mangrove forest over a newly formed delta in the Umhlatuze Estuary, South Africa

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Received 18 January 2001, accepted in revised form 5 March 2001

Different age groups were recognised in a mangrove forest that progressed over a delta forming after the construction of a harbour in the Umhlatuze Estuary, South Africa in 1976. The rate of progress was high during the first period, varying from 20 to 55ha year^{-1} until 1982. Thereafter there was a small decrease in the total area, whereas the rate has been 5.4ha year^{-1} over the last 13 years. Diameter at breast height (dbh) and densities of trees and seedlings were investigated in the field in the different age groups recognised from the aerial photo record covering the area. The youngest stands (1–6 years old trees) had a significantly lower mean dbh compared to the older stands (>6 years). The difference was also clear when it came to stem densities, where significantly higher densities were found in the youngest stands. The mean density of live seedlings was high in the youngest stands, being significantly lower in the older stands. When it came to the mean density of dead seedlings, the number from the youngest stand was lower than the ones obtained for older groups. The oldest group had however a very low density. It is suggested that the mangrove progression has slowed down, thus indicating that the system is settling down.

Introduction

In the beginning of the 1970's it was decided to develop a deep-sea harbour in the Umhlatuze Estuary close to Richards Bay, South Africa (Figure 1).

In order to avoid problems with sedimentation within the harbour area, the Umhlatuze River was canalised and redirected southwards, entering the Sanctuary Area. Moreover, the tidal flushing in the sanctuary was restored by breaching a new mouth through the dunes. Shortly after the constructions were completed, the mangrove forest started to expand over a delta forming where the Umhlatuze River enters the sanctuary. The colonisation of this delta was made possible mainly due to an increase in the tidal range from 0.4 meters before to 1.4 meters after the construction (Huizinga and Van Niekerk 1998), leading to the exposure of the delta area at low tide. An increase in sedimentation probably contributed some to this effect as well (Cooks and Bewsher 1993, Huizinga and Van Niekerk 1998). Since there are aerial-photos covering this area during the period concerned, it is possible to recognise when the different parts of the delta were colonised and thereby estimate the age of the mangrove stands.

The objective of the study was to map the progression of the mangrove forest over the newly formed delta and describe structural properties of the different age stands. This information is needed for further management of the estuary and it will give indications on how the further development of the mangrove forest will take place. Furthermore, it afforded a good opportunity to follow the development of a mangrove forest from colonisation to maturation.

Methods

Study Site

The Umhlatuze Estuary (3 000ha, 28°47'S to 28°51'S and 32°00'E to 32°06'E) is located just outside the city of Richards Bay in the province KwaZulu Natal in South Africa (Figure 1). The main river entering the estuary is the Umhlatuze River with an average flow of from 350–500m^3 sec^{-1} during summer and about 250m^3 sec^{-1} during winter, however, the river almost cease flowing in the winter (Cooks and Bewsher 1993). The mangrove forests are mainly located in the southern and western parts of the estuary with the species *Avicennia marina* (Forssk.) Vierh., *Bruguiera gymnorrhiza* (L.) Lam. and a few *Rhizophora mucronata* Lam. occurring there. Our study area is located in the western parts (Figure 3) and consists mainly of monospecific stands of *A. marina*. The mangroves are covering an approximate area of 427.5ha (Steinke 1999) making it the largest mangrove forest in South Africa.

Study procedure

The progression of the mangrove forest was mapped by

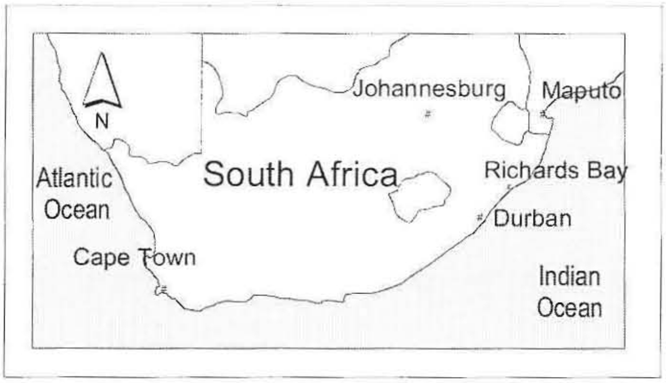

Figure 1: The location of Richards Bay in southern Africa. This involved the construction of a berm wall across the estuary, dividing it into two parts (Figure 2a and b)

examining the aerial photo record from the period 1974 to 1999. The mangrove stands were classified in three different groups: Dense, spaced or scattered. Dense stands were appearing as continuous mangrove stands with a closed canopy. In situations when the canopy was not closed, the class spaced was used. The term scattered was applied when the stands were far apart from each other but the boundaries to uncolonised area being distinct. Sandbanks and mudflats were also mapped.

Based on when a specific area was colonised, 5 different age groups were recognised, as shown in Table 1. The age groups were sampled in the field using randomly chosen quadrats within the age groups. Edge habitat was avoided since trees growing in edges experience different environmental properties than tress growing in the interior. This would lead to differences in structure that could not be explained by differences in age. The size of the quadrat was usually 15 x $15m^2$, however, in very dense stands smaller quadrats were used. Diameter at breast height (dbh), by convention 1.3 meters above the ground (Cintrón and Schaeffer-Novelli 1984), was measured for all trees taller than 2m within a quadrat. Trees shorter than 2m and saplings (1–1.5m) were measured at half height. Plants shorter than 1m were considered as seedlings and just counted and classified as being dead or alive. For trees branching below breast height, all the stems at breast height were measured. It was noted whether the trees were alive or dead, alternatively if only some of the branches were dead. Seedlings were sub-sampled in each of the quadrats. Usually all the seedlings at the site were sampled, but when seedling densities were high, they were sampled over a smaller area. The condition of the seedlings was also registered, i.e. whether they were dead or alive.

For calculation of mangrove areas, the information from the mapping was digitised using PC Arclnfo 3.1. Points on the ground that were recognisable on the aerial photos were measured using a GPS (Garmin XL 12). These points were used for adjustments of the scale of the aerial photos.

Results

The mean annual rate of expansion of the mangrove forest has changed in the period examined (Figures 4 and 5). In the period from 1974 to 1980 the annual rate was about 20ha year^{-1}, increasing to over 55ha year^{-1} during the next two years. In the 5-year period preceding 1986 the rate was negative (-1.6ha year^{-1}), rising to an average of 5.4ha year^{-1} over the last 13 years.

Shortly after the completion of the berm wall and the breaching of a new mouth, the system was very unstable. The cross sectional area of the new mouth was varying between 300 and $650m^2$ (Huizinga and Van Niekerk 1998) causing great changes in the tidal regime. Redirection and canalisation of the river lead it outside the original mangrove swamps and delta area, making the river's connection with the sea better. Furthermore there was a flood in 1977 causing additional disturbances in this period. It was reported that 'the sanctuary is full of logs, debris and floating islands' (Anon 1977). From aerial photos it is also evident that there has been a flush out of sediments and newly established plants. Even though large areas were available for colonisation, a relatively small area was colonised. Most of the increase in mangrove area was made out of newly established seedlings. However, during the next two years (1980 to 1982) the delta experienced a massive colonisation and all habitats suitable for establishment of mangrove seedlings

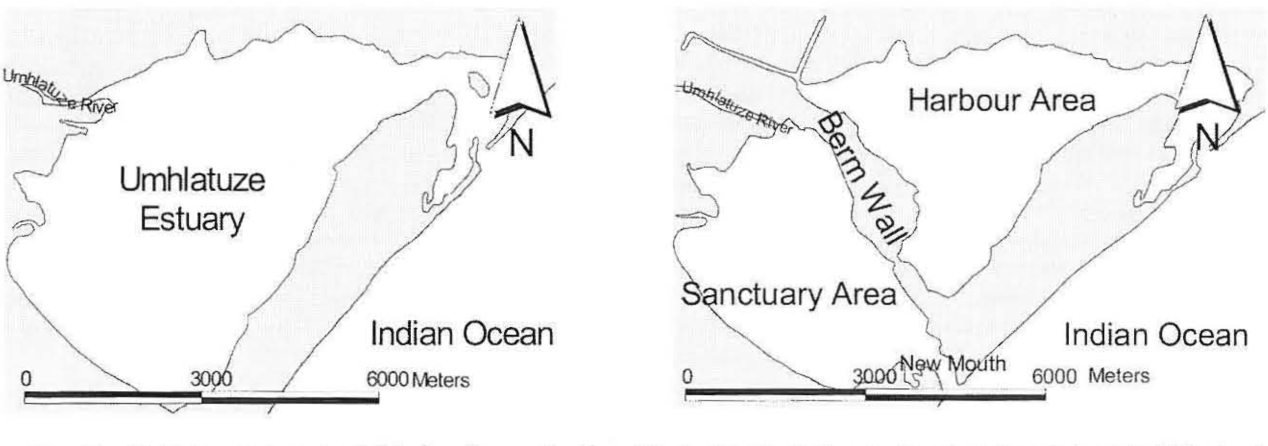

Figure 2: a. The Umhlatuze Estuary in 1968 before the construction of the harbour took place **b.** The Umhlatuze Estuary in 1976 after the construction of the new harbour was completed (Cooks and Bewsher 1993)

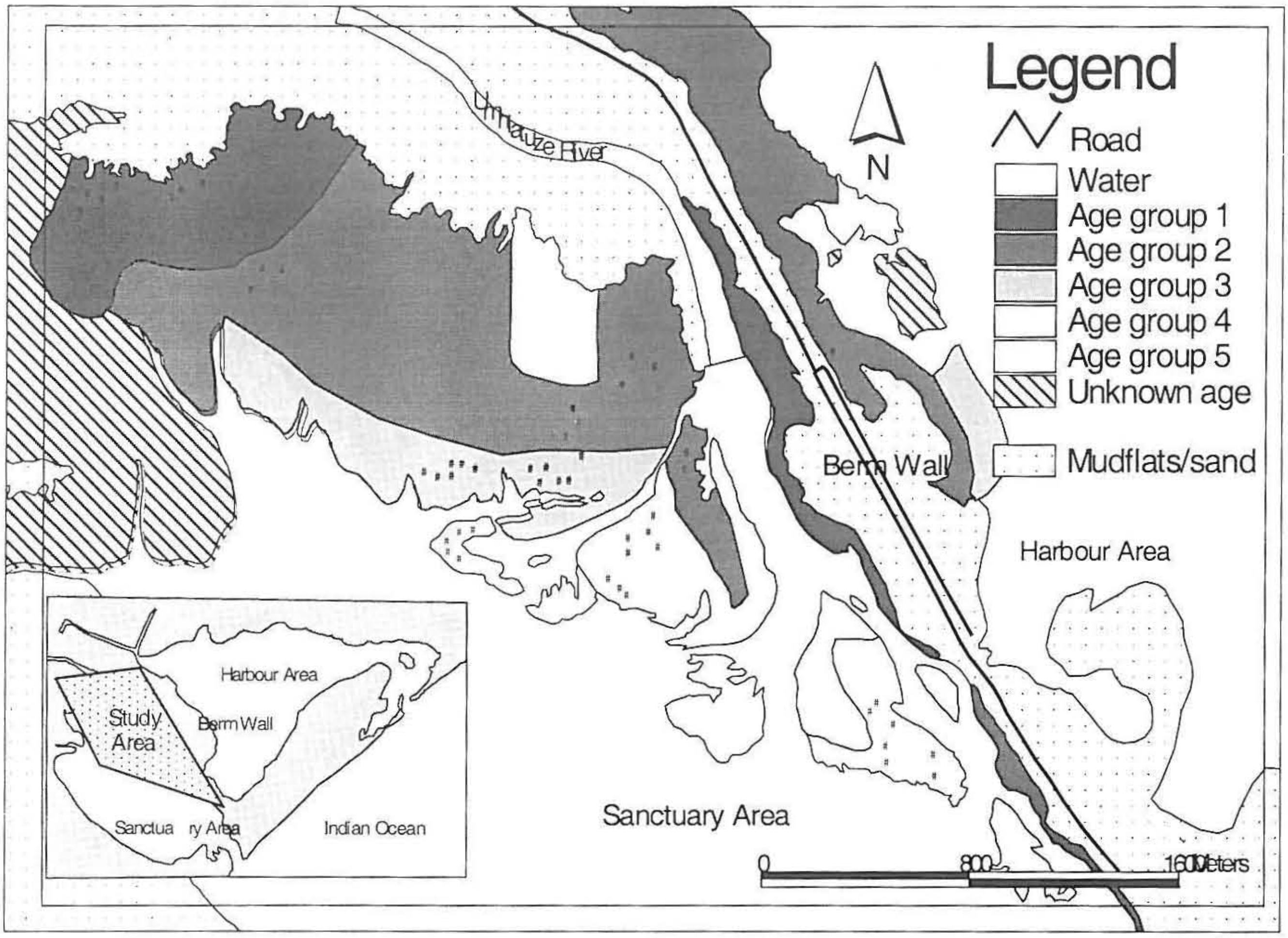

Figure 3: The different age groups recognised in the mangrove of the Umhlatuze Estuary. Each quadrat is indicated with a #. The study area is indicated in the insertion

was colonised at that time. No major floods were recorded for this period. The scattered stands developed into more dense stands during the next period from 1982 to 1986. During this period there was in fact a small decrease in total mangrove area. This can partly be explained by the flooding caused by the Domoina and Imboa Cyclones in 1984 that may have caused newly established seedlings (and saplings) to be covered with sediments or merely flushed away. This was the case in the Lake St Lucia Estuary 70km north of the Umhlatuze Estuary where propagules and flowering material were lost in the flood waters accompanied by the cyclone and thereby reducing establishment of seedlings the same year as well as causing minimal propagule production the following year (Steinke and Ward 1989).

Table 1: Age groups used for classification of mangrove stands

Group	Colonising Years	Arrpoximate Age
1	Before 1978	> 20 years
2	1979–1983	16–20 years
3	1984–1988	11–15 years
4	1989–1993	6–10 years
5	1994–1999	< 6 years

During the last 13 years the expansion rate was relatively low (5.4ha $year^{-1}$). A flood in 1987 could probably have caused similar effects as indicated for the 1984 cyclones, but the low rate can also be contributed to the fact that suitable habitat for mangrove colonisation was not as abundant as it was in the earlier periods, merely because it had already been colonised.

The results of the investigation of the structural parameters are presented in Figure 6 and 7. It should be mentioned that the data obtained on *B. gymnorrhiza* is left out of the calculations. Its occurrence was very rare and including them would only have complicated the statistical analyses. The results therefore only apply for *A. marina*.

The results show that the mean dbh in the youngest age group (Group 5) was significantly different from the mean dbh in the older age groups (Group 1–4) (Figure 7a). This can also be shown by examining the relative proportion of the size classes for the different age groups: There was a high proportion of small dbh (0–9cm) in the youngest group, whereas the older groups had a higher proportion of large dbh (10–49cm) (Figure 6). This suggests that mangrove development is rapid and within 6–7 years after colonisation

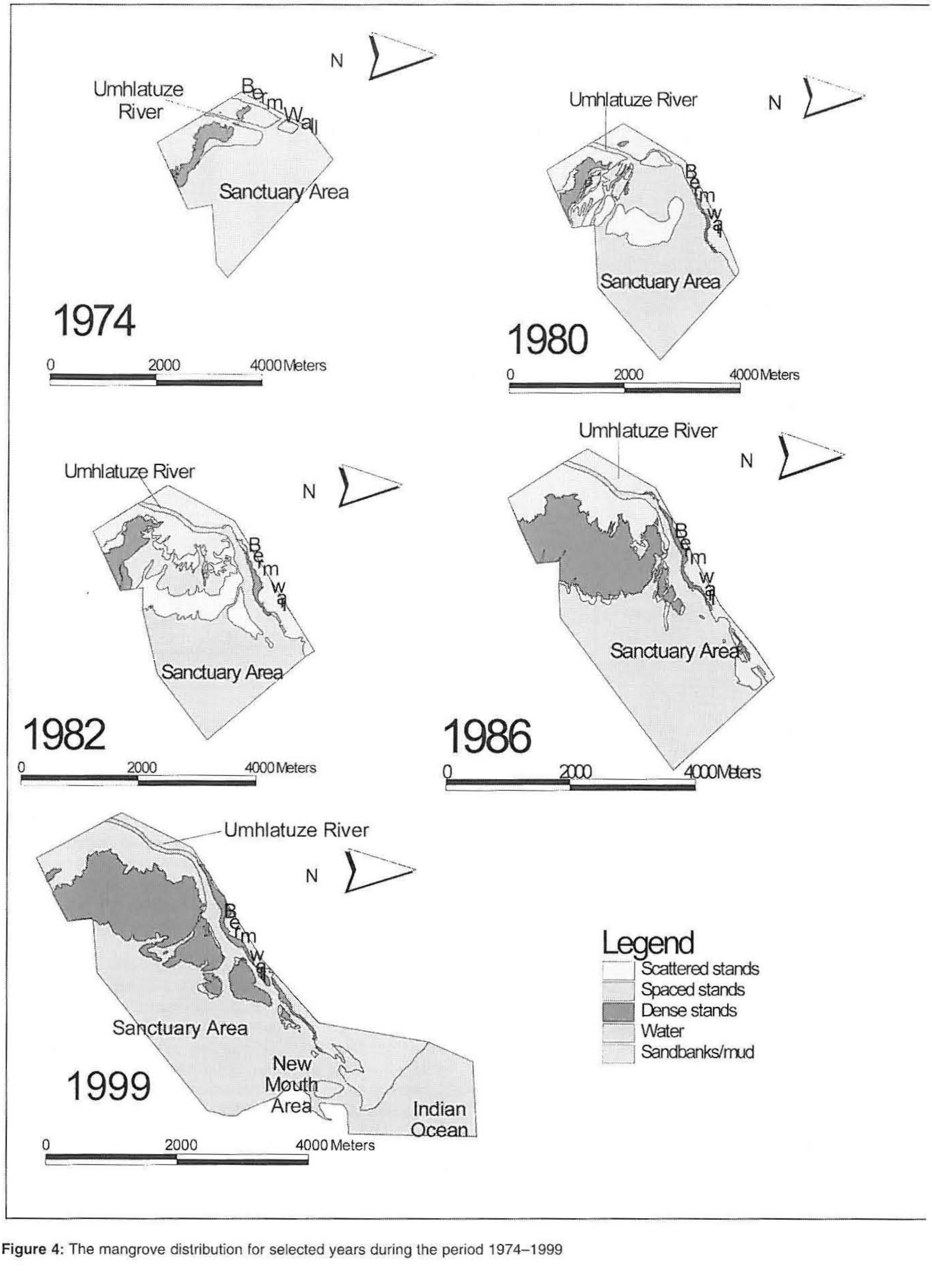

Figure 4: The mangrove distribution for selected years during the period 1974–1999

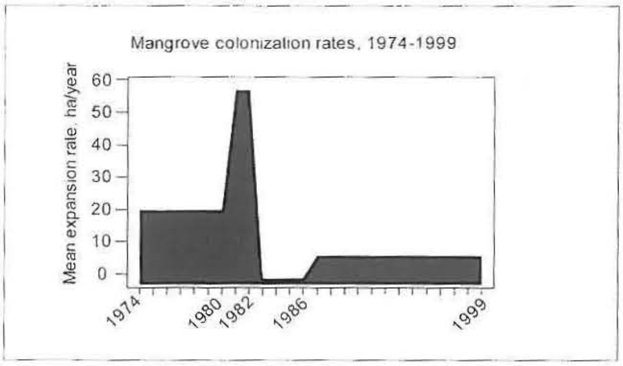

Figure 5: The rate of change in the mangrove area during the period 1974–1999

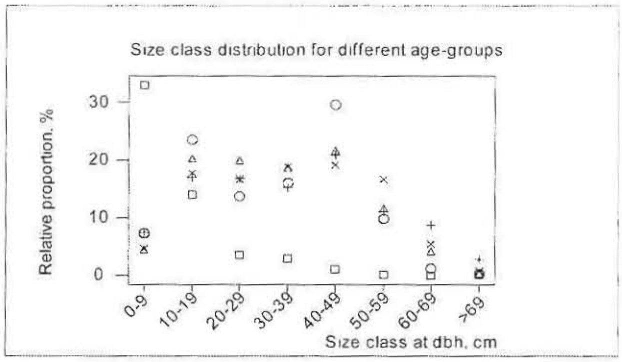

Figure 6: The size class distribution in the different age groups: ○ (1974–78), + (1979–83), x (1984–88), ▯ (1989–93), □ (1994–99)

the stands have developed into mature stands. The small variation between the four older age groups indicates that the forest structure, when it comes to the size of the trees, does not change much after this stage is reached. Therefore, it seems like this mangrove forest structurally can be divided into just two groups, that is: Newly established, young stands or mature stands where the trees are usually older than 6–7 years. This is supported by the data obtained on mean stem densities at breast height in the different age groups (Figure 7b). Again the youngest age group was significantly different from the four older groups in which the densities were stable and lower. The mean density of live seedlings was found to be highest in the youngest age group (Group 5) (Figure 7c). It was significantly lower in the older groups, however, the group from the period 1979 to 1983 (Group 2), had a higher mean density than the others. Looking at densities of dead seedlings, we found increasing mean densities moving into older stands, except for the stand where colonisation took place before 1978, in which the mean densities were very low (Figure 7d).

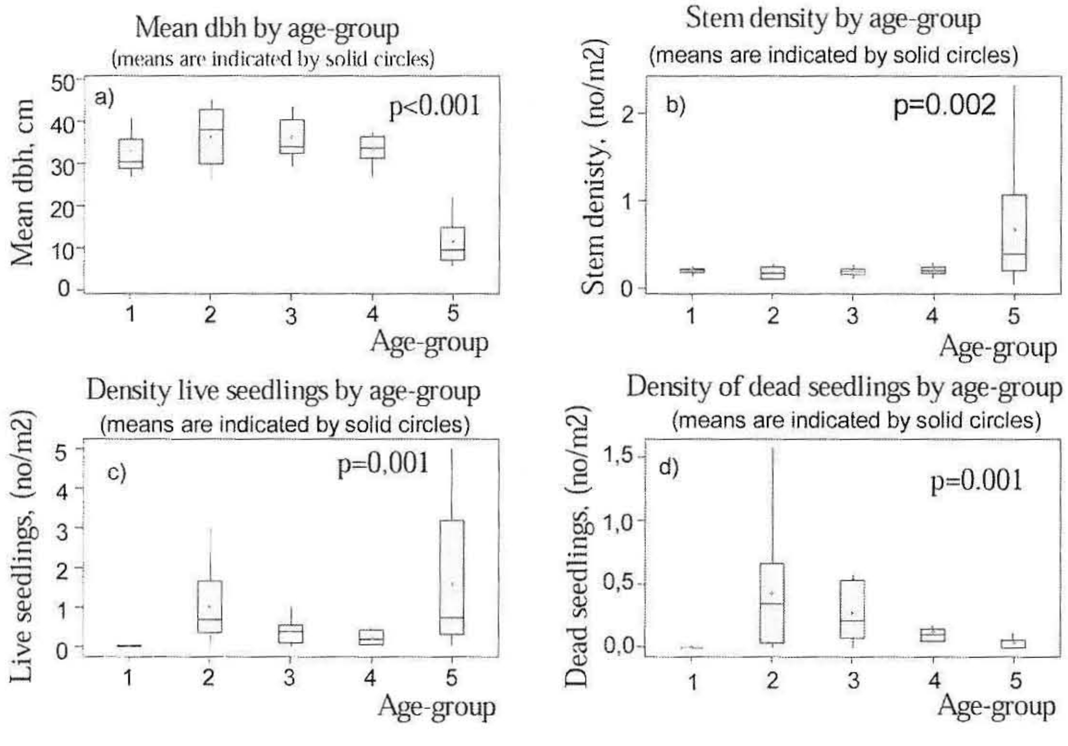

Figure 7a–d: The mean diameter at breast height in different age-groups

Discussion

The rapid establishment of *A. marina* that was pronounced during the first period has also been observed by other authors. It is also in agreement with that the species is considered to be a pioneer in mangrove communities (Steinke 1999, Adams *et al.* 1998).

Stem densities are closely linked to the dbh, as it is expected that number of stems that can occupy a quadrat is smaller when the diameters are large. The great variability found in the youngest age group can be explained as follows: This group is either characterised by I) A large proportion of saplings and small trees within the quadrat or II) One or two large, very branched trees with some small trees and saplings adjacent to these. The large trees probably supply the surroundings with propagules as it is observed for *A. marina* that propagules mainly strand and establish close to their parents, however they can also be transported further away (Clarke 1993). The first situation will lead to a high density whereas the latter means that a low density will be experienced. The small size of quadrats (5 x 5m^2) used in the youngest stands would result in some of them containing only seedlings and saplings, whereas other quadrats would contain a 'parent' tree as well. The use of larger quadrats could have been one solution to avoid this over estimation of densities.

It is difficult to explain why mean density of live seedling was highest in the youngest age group in comparison to the effect of different ages, as seedling densities for *A. marina* is dependent upon various factors, such as availability of propagules and inundation frequencies (Lee *et al.* 1996).

The number of dead seedlings can give us an impression on how the survival of seedlings to the sapling stage is, i.e. a high proportion of dead seedlings would mean that the survival to the sapling stage is low. The increasing mean density of dead seedlings in the older groups can possibly be explained by the fact that these groups are stable, few gaps are created and thereby few possibilities for seedlings to develop to the sapling stage. It is recognised that sufficient light is necessary for reaching the sapling stage as well as the availability of nutrients (Clarke and Allaway 1993). Why the seedling densities in the oldest group are very low can be dependent on various factors. Predation by crabs (Clarke and Myerscough 1993), substrate characteristics, inundation frequency and availability of propagules (Lee *et al.* 1996) are possible factors that can explain the amount of seedlings at a site.

Mangrove colonisation is less rapid today, compared to the decade after the impoundments took place, merely because the amount of habitat available is much less today. The availability of propagules does not seem to be a limiting factor. The system does not seem to be severely affected by the floods that have occurred during this period, extensive sedimentation has not taken place and there has not been a major damage of the mature mangrove stands. It can therefore be concluded that the system probably has settled and that there will be no major mangrove expansion in the future, unless the system experiences further perturbations like the one in the 1970's. The situation of the new mouth should be monitored, however, since the size of this is the major determinant of the tidal regime in the system and thereby the areas that can be vegetated by mangroves.

Acknowledgements — First of all I would like to thank Ricky Taylor, who suggested this project and who has been supporting me throughout the whole process. Professor Sylvi Haldorsen and Associate professor Ørjan Totland at the Agricultural University of Norway have acted as my supervisors and their involvement is highly appreciated. The late Professor Adelaida Semesi at the University of Dar-es-Salaam should also be mentioned for helping me out with the set up of the fieldwork and for comments on the results. The staff at KwaZulu Natal Conservation Service in Richards Bay should also be thanked for helping me with all the practical issues and assistance in the field. Thanks to the staff at PortNet, Richards Bay, who very willingly let me use their aerial-photos record over the area. I also received financial support from Noragric and the State Education Loan Fund in Norway that was highly appreciated.

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Edited by M Björk and RN Pienaar